ACAS Monitoring Evaluation Report

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Abstract

This document constitutes the closing report of the ACAS Ground Monitoring prototype system evaluation. The report enlarges and completes the preceding initial and final system data evaluation and system prototype verification, whereas the project team turns its attention and considerations to the overall system, to the system components and its boundaries.

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This deliverable consists of SJU foreground.

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Executive summary

This document sums up and concludes the results of the system evaluation and the verification tests of the ACAS ground monitoring system prototype. The evaluation concerns the inspection of the entire prototype system. It comprises the analysis of all relevant RA event data as well as the practical realisation of the verification exercises as described in the related test documents (refer to [23] and [24]).

The methods to verify the ACAS ground monitoring system requirements were:

If the system operation in a real traffic environment and if real Resolution Advisory (RA) event data are not available or useless, the usage of corresponding tools to simulate needed RA events (RF signal generator) is applied.

The project focuses mainly on the data, which were sent, received and processed on internal and external system interfaces. For the evaluation the project developed dedicated recording & replay tools.

This document joins, explains and extends the results of the initial and final data collection and evaluation and system verification processes.

The considered ACAS ground monitoring system is at this stage a field-proven prototype. Some minor observations were found by the project team during the testing, but in general all essential system requirements are covered and fulfilled and the prototype passed the verification tests successfully.

Note:

It is just a minor step to get the considered ACAS ground monitoring system ready for the usage in a real operational ATM environment.

Figure 1 illustrates the coverage of the ACAS ground monitoring system installed partly by the Project within the German airspace. The coverage of the two additional SESAR Project 15.04.03 ACAS ground station sensors indicated in blue colour. All connected ACAS sensors are sending their received ACAS RA event data via a dedicated network for further processing to the ACAS centre in Frankfurt-Langen, where the ACAS server is located.

Remark: The SESAR 15.04.03 sensors are extending the DFS AMOR system.

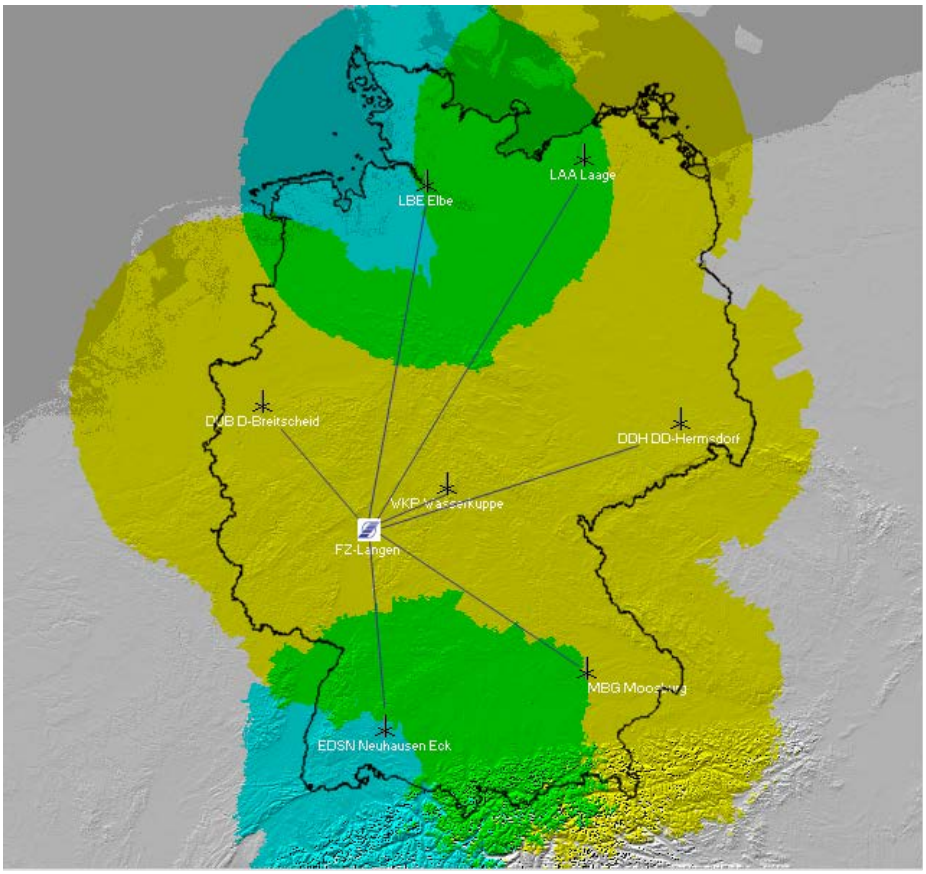


Figure 1: ACAS Ground Monitoring System

1 Introduction

1.1 Purpose of the document

The present document

- evaluates unconsidered aspects of the data evaluation and the system verification
- describes the relationships between the data evaluation and the system verification
- summarizes the results of the data evaluation and the system verification

The subjacent system architecture is described briefly in Figure 2.

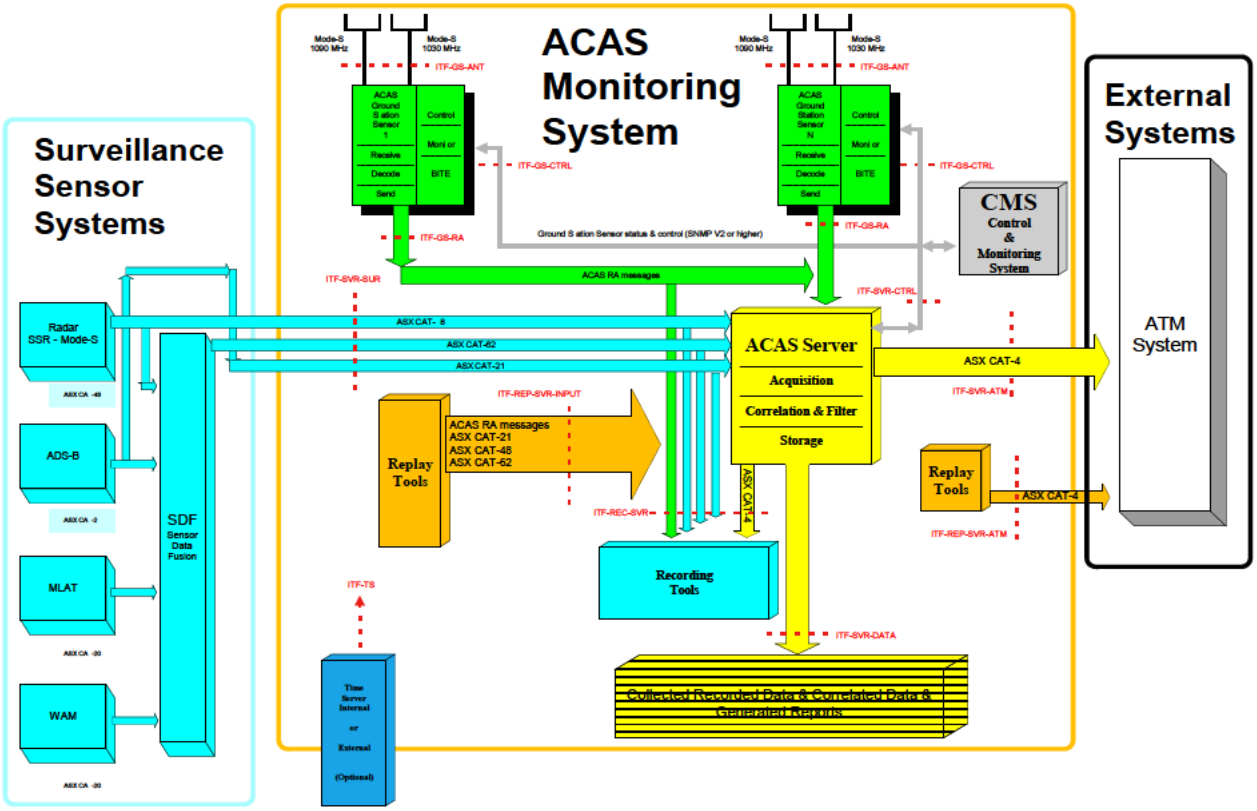


Figure 2: ACAS Ground Monitoring System Architecture

The base document for ACAS ground monitoring evaluations constitutes the document deliverable SJU 15.04.03 D03 [21].

Additional documents contributing to this paper are the data evaluation report SJU 15.04.03 D10 Final Data Collection [24] and the evaluation of the verification exercises in SJU 15.04.03 D05 [23].

The present ACAS Monitoring Evaluation Report considers the separate parts of the ACAS Monitoring System Architecture and discusses the corresponding contributions of data evaluation and system verification.

The considered topics are the functional system components illustrated in the following Figure 3.

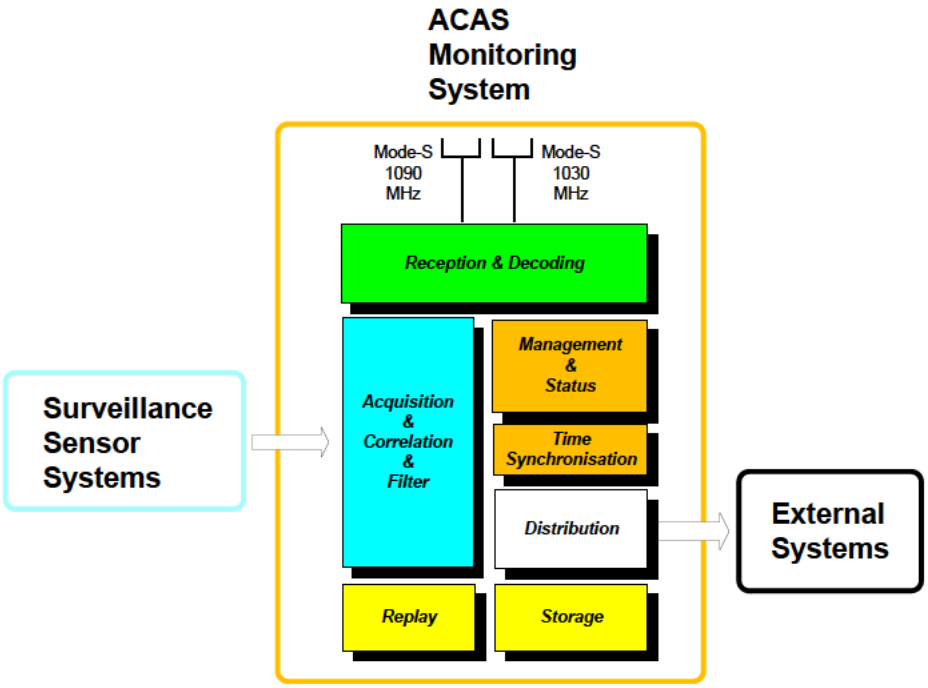


Figure 3: ACAS Ground Monitoring System Functions

1.2 Intended readership

This report references parties, which are interested in the feasibility of an ACAS ground monitoring system.

1.3 Structure of the document

The present document goes through the functions of the ACAS ground monitoring systems and describes the related contributions of the system components.

The contributions of the system components are derived from the documents SJU 15.04.03 D10 Final Data Collection [24] and SJU 15.04.03 D05 [23].

1.4 Glossary of Terms

1.5 Acronyms and Terminology

Term	Definition
1090 ES	1090 MHz Mode S Extended Squitter
1090 GS	ADS-B 1090 MHz Extended Squitter Ground Station
ACAS	Airborne Collision Avoidance System
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance - Broadcast
ANSP	Air Navigation Service Provider
ARA	Active Resolution Advisories
ASTERIX	All Purpose Structured EUROCONTROL Surveillance Information Exchange
ATC	Air Traffic Control
ATM	Air Traffic Management
BDS	Comm-B Data Selector
BITE	Built-In Test Equipment
CMS	Control and Monitoring System
Comm -A	Short Uplink Communication Message (Mode S)
Comm-B	Short Downlink Communication Message (Mode S)
Comm-C	Long Uplink Communication Message (Mode S)
Comm-D	Long Downlink Communication Message (Mode S)
CRC	Cyclic Redundancy Check
DF	Downlink Format
E-ATMS	European Air Traffic Management System
ES	Extended Squitter
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FDPS	Flight Data Processing System
FMS	Flight Management System

Term	Definition
GPS	Global Positioning System
GS	Ground Station
Hz	Hertz
I/O	Input and/or Output
ICAO	International Civil Aviation Organization
IP	Internet Protocol
LDAP	Light Weight Directory Access Protocol
LSB	Least Significant Bit
MB	Message field in Comm-B (Mode S)
MC	Message field in Comm-C (Mode S)
ME	Message Field in Extended Squitter
MHz	Megahertz
MOPS	Minimum Operational Performance Standards
MSB	Most Significant Bit
MSL	Minimum Signal Level
MTL	Minimum Trigger Level
N/A	Not applicable
NM	Nautical Mile
NTP	Network Time Protocol
PD	Probability of Detection
RA	Resolution Advisory
RADL	Resolution Advisory Downlink
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
s	Seconds
SAC	System Area Code of data source
SESAR	Single European Sky ATM Research Programme

Term	Definition
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SIC	System Identification Code of data source
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Program	The program which addresses all activities of the SESAR Joint Undertaking Agency.
SNMP	Simple Network Management Protocol
SSR	Secondary Surveillance Radar
TA	Traffic Advisory
TCAS	Traffic Alert and Collision Avoidance System
TCP	Trajectory Change Point
TMA	Terminal Area
TOA	Time of Applicability
TOMR	Time of Message Reception
UDP	User Datagram Protocol (an Internet Protocol)
UF	Uplink Format
UTC	Universal Time Coordinated
WAM	Wide Area Multilateration
WGS 84	World Geodetic System 1984

2 Context of System Evaluation

2.1 System Data Reception and Decoding

General:

The reception and decoding functions are located in the ACAS ground station sensor. Main tasks of these functions are:

- The reception & detection of 1090/1030 MHz Mode S signals
- Decoding of the Mode S signals
- Filtering of related Mode S telegram types
- Distribution of decoded Mode S telegrams (Raw data) via network to ACAS server

2.1.1 TCAS Message Types

Data Collection Evaluation:

The evaluation of the data collection [24] shows that the ACAS ground station sensors are capable to receive and process all relevant RA Event data, which are sent out by transponders compliant to the TCAS II versions 6.04A (DO-185 [16]), 7.0 (DO-185A [17]) and 7.1 (DO-185B [18]).

The data evaluation has proven that there is one transponder type, which does not correctly report its TCAS version. Transponders of this type pretend to be of version 6.04A, although being of version 7.1. Latest observations of the German airspace at the beginning of 2013 have shown that the problem in the transponder type is still exists.

Evaluated TCAS versions:

Even if the structures of the evaluated TCAS II versions are not identical, the ACAS ground station sensors are capable to receive and process all of them.

2.1.2 Latency and Probability of Detection

General:

Key part of the system is the correct and in time processing of valid RA events to external ATM systems (controllers). Main concern was to minimize the time duration between the indication of an RA event in the cockpit, and the distribution of the event over the network to the ATM system. The project team evaluated several times varied tests and analyzed the system's latency.

Data Collection Evaluation:

The evaluation of the data collection [24] has shown that the latency requirements (less than 2 seconds) can be achieved by the current system prototype.
Analysis of the RA event related data flow through the systems shows that the processing time and distribution of the data via network do not really affect the latency.
As already stated in earlier studies, for RA downlink the rotation dependent detection time of the RA event has been identified as the main cause of the delay

Requirement Verification:

The test of exercise "EXE-15.04.03-VP-130 Latency" has shown that the latency is much less than 2 seconds, if the RA event data and surveillance data are injected with signal generators or RA event simulators. To improve the latency with real data, it is possible to evaluate the Enhanced MB Data part of the downlink formats DF 20 and DF 21. If the subfield DR (Annex 10 IV 3.1.2.6.5.2 [8]) of the Enhanced MB Data contain the ACAS reserved values 2,3,6 or 7 and the MB Data start with 30, then the MB Data can be interpreted as RA event data of the corresponding register. The content of the

register corresponds to the content of the related UF 30/31 RA Broadcast message being evaluated by the radars and sent via ASTERIX CAT 048.

Recommendation:

It is recommended that the received downlink telegrams DF20 and DF 21 in the ACAS ground station sensors are activated and distributed to the ACAS server. If the sensors of the ACAS ground monitoring system can receive the aircrafts replies to the radars' interrogations of the BDS 3,0 register, then the needed information is immediately available to the ACAS ground monitoring system and can be processed. The latency will decrease conspicuously; the probability of detection within the 2 s limit after the RA event improves itself.
The following Figure 4 taken from [24] illustrates the latency of RA events, if the BDS registers of DF20 and DF21 telegrams are not evaluated. The delay is in average 1300 ms before a PD of 90% is reached.

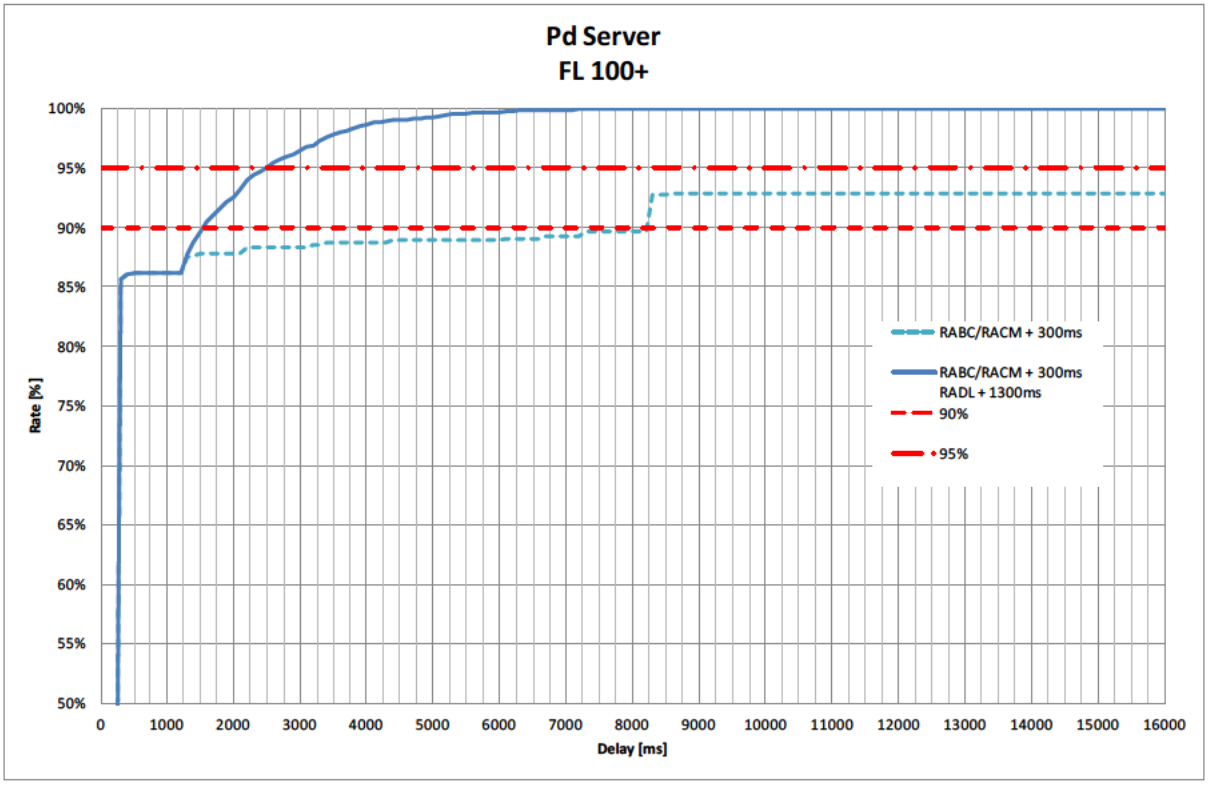


Figure 4: PD and Latency RA Broadcast only

Activating the evaluation of the DF20/DF21 telegrams improves the latency demonstrated by the snippet shown in Figure 5. The first two columns show the time of message reception at the ACAS server and sensor, the third column the message type.

Server	Sensor	Type	Alarm
18:23:44.601	18:23:44.581	DF20	active
18:23:44.602	18:23:44.580	DF20	active
18:23:44.725	18:23:44.705	DF20	active
18:23:44.716	18:23:44.704	DF20	active
18:23:45.151	18:23:45.133	DF20	active
18:23:45.659	18:23:44.710	RADL	active
18:24:08.430	18:24:08.426	DF20	terminated
18:24:08.438	18:24:08.426	DF20	terminated
18:24:09.066	18:24:09.054	DF20	terminated
18:24:09.532	18:24:09.512	DF20	terminated
18:24:09.796	18:24:08.437	RADL	terminated

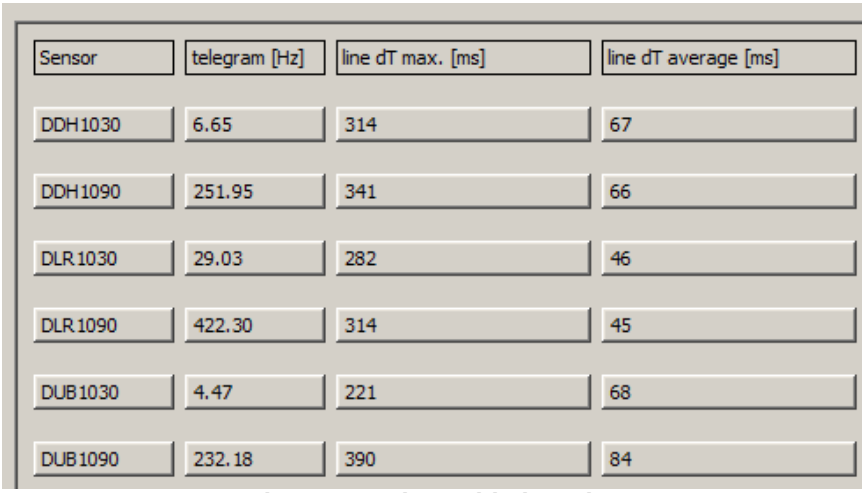
Figure 5: PD and Latency with DF 20 and DF 21

This extract of a recording with activated DF20/DF21 evaluation shows that the DF20/DF21 data are received before the RA downlink (RADL), which is requested by the radars.

The measured latency of the exercise using an ACAS Ground Station Sensor in the laboratory was always far below 100 milliseconds. Statistical measurements of the network delay between the sensors and the server in the examined coverage have shown a maximal value of less than 600 milliseconds.

Figure 6 shows a statistical measurement of some sensors of the coverage.

- The first column shows the abbreviations of the considered sensors;
- the second column shows the average number of received telegrams,
- the third column the maximal delay and
- the last column the average delay.



Sensor	telegram [Hz]	line dT max. [ms]	line dT average [ms]
DDH1030	6.65	314	67
DDH1090	251.95	341	66
DLR1030	29.03	282	46
DLR1090	422.30	314	45
DUB1030	4.47	221	68
DUB1090	232.18	390	84

Figure 6: Delay cable lengths

2.1.3 Coverage

General:

The project objective was to cover the German airspace above FL100 with a minimum amount of ACAS ground station sensors. After several site surveys and evaluation of the environment the project decided to expand the current installed AMOR system by two additional ACAS ground station sensors, whose positions and expected detection cover ranges are marked in Figure 1 in blue color.

Data Collection Evaluation:

The initial and final data collection and evaluation tasks have shown that the amount of eight ACAS ground station sensors is sufficient to cover the air space of Germany above FL100.

Requirement Verification:

The requirement is proven with the analysis of the collected data (initial and final data collection tasks).

Recommendation:

The current probability of detection of the monitored airspace is fine, but it should be improved for operational usage by further ground station sensors.

2.1.4 ACAS Ground Station Sensor Data

General:

The ACAS ground station sensors receive, decode and distribute 1090/1030 MHz Mode S RA event data. The sensors are able to filter Mode S data by their downlink/uplink formats.

Requirement Verification:

The tests have shown that the ACAS ground station sensors have the capacity to receive all defined uplink formats on the 1030 MHz channel and all defined downlink formats on the 1090 MHz channel.

The inclusion of the downlink formats DF 20 and DF 21 permits, in addition, to extract the register BDS 3,0 from the Enhanced MB data, which allows an evaluation similar to Mode S RA downlinks.

It is possible to read the register BDS 3,0 from DF20 and Df21 telegrams checking the DR (Downlink Request) Field. The DR Field contains the register, which has been interrogated by radar.

If DR (Annex 10 IV 3.1.2.6.5.2 [7]) contains the ACAS reserved values 2, 3, 6 or 7 and the MB Data starts with 30, then the ACAS Ground Monitoring System can interpret the MB Data as RA event data.
According to Annex 10 [7] chapter IV paragraph 4.3.11.4.1 the radar interrogates the target with RR = 19.

The ACAS Ground Monitoring System supports also aircraft transponders compliant to ED102A/DO-260B [19].
In that case, the ACAS Ground Monitoring System extracts the needed RA event data directly from the appropriate ADS-B extended squitter telegrams (e.g. DF17).

The system allows the filtering and forwarding of only dedicated Mode S telegrams types and subtypes for further processing.

Recommendation:

The project recommended to let the ACAS ground station sensors receive and process at least the formats UF16 and DF 16 (ACAS RA event messages), DF 17 (ADS-B advisory reports) as well as DF 20 and DF 21 (BDS 3,0 register).
The sorted out telegram formats relieves intensely the internal communication (network load/bandwidth) between ACAS ground station sensors and ACAS server.

2.1.5 Invalid Telegrams

General:

The project team pays attention to the reception of invalid RA event data, which shall be detected and filtered by the ACAS ground monitoring system automatically.

Data Collection Evaluation:

The evaluation of the collected data [24] shows that 99% of the received RA downlink telegrams contain invalid data. Those telegrams received correctly by the ACAS ground station sensors (pass the internal checks and error correction), but they must be filtered out later in the ACAS server.

Requirement Verification:

The requirement verification shows that the ACAS ground station sensors are capable to provide error corrections on received telegrams, which fail the decoding of the Reed-Solomon algorithm. Telegrams, which cannot be corrected, can be dropped in the ACAS ground station sensors. Once a telegram passed this check there is however still no warranty that the content of the telegrams is valid.
The ACAS server marks not only invalid data, but also valid data, which cannot be used. Unused data are for example RA event messages that cannot be correlated to any target of the surveillance data.
Figure 7 shows an extract from a log file daily.log. Every row contains RA event messages composed of the type of source (1090 MHz (‘000’), 1090 MHz (‘001’) or RA downlink from ASX CAT 048 (‘002’)), the received data source (SAC/SIC), date and time of reception, the payload and in the last column the flag, if the message is used (value ‘1’) or not used (value ‘0’).

```
000 098 180 [date and time] 866EBF813A803C07FEFA42BB48EC 0
000 098 180 [date and time] 8646F9623F9A727A0A1AC227AA81 0
000 098 179 [date and time] 817C850D3C4B1899455E8930DB03 0
000 098 177 [date and time] 838F1A9F331200401A43829590FE 0
000 098 179 [date and time] 822914023114000C1E08006E4573 0
002 098 098 [date and time] 30C00008002041 3c5464 1
002 098 098 [date and time] 30C00008002041 406532 1
000 098 188 [date and time] 842AAEFD3D3F65BFFB8013036BCA 0
```

Figure 7: Daily log

2.2 Acquisition, Correlation and Filter

The acquisition, correlation and filtering function is located in the ACAS server.

The correlation of the resolution advisory event data comprises the correct interpretation of ACAS RA event messages and the assignment to the concerned aircraft surveillance data.
The system does not only process RA event data, it also correlates and links associated aircraft track history data. Here the system tries to link aircraft track data before and after the RA event. This allows the user to analyse better the situation of an RA event afterwards.

2.2.1 Performance

General:

The ACAS ground monitoring system is capable to process several RA events in parallel.

Data Collection Evaluation:

The evaluation of data collection [24] has shown that the load on the ACAS Server is negligible low. But nevertheless, the system user should always regard the amount of connected ACAS ground station sensors and Surveillance data sources due to the network load.

Requirement Verification:

The simultaneous handling of 10 RA events has no real effect on the ACAS server performance, but other observations were made.

The verification was performed on real traffic by assigning artificial RA events to arbitrary targets. Some of the 10 targets selected for the verification test had the same Mode 3/A code. The Mode 3/A code is the non-unique identification used to assign Resolution Advisory Event messages to aircraft, when the Resolution Advisory information is taken from the UF 16/31 Resolution Advisory broadcast message. In particular this condition will be major factor in the future, due to the fact that in Europe most of the city liners are linked to the same Mode 3/A code (octal 1000), which is suppressed in ADS-B data by the transponders.

Recommendation:

In case of non-unique Mode 3/A codes, it is often impossible to identify the affected aircraft. In the cases, where the RA event messages cannot uniquely be correlated to a target, they shall be ignored.

2.2.2 Surveillance and Ground Station Sensor Data

General:

The system is able to process input of user defined surveillance and ACAS ground station sensor data. That means that the user could activate or deactivate specific ACAS ground station sensor and Surveillance sensor systems inputs.

Requirement Verification:

Deviating from ASTERIX CAT 048 standard, the verified ACAS monitoring system uses an ASTERIX CAT 048 data stream (AMOR environment), which contains a non-standard 6 bytes long prefix per record. This prefix must be ignored by the ACAS server. The feature to skip these 6 bytes is configurable in the ACAS server.

The long term check on the recorded contents of RA data log-files from real traffic confirmed that the ACAS server and tools are capable to receive the surveillance data formats ASTERIX CAT 021, CAT

048 and CAT 062. A main issue and challenge for the project team was that the surveillance data were sent to identical network IP addresses and ports over the test network.

The system is capable to filter Surveillance and Ground Station Sensor Data based on their data source identifications (SAC and SIC value). The user could configure the filter himself. If the filter list is empty, no filtering is applied. If the list contains data sources (SIC/SAC values) then only the data of the listed sources pass the system.

Remark: The filter list can currently only be edited with an ASCII editor.

2.2.3 Duplicate and Invalid Information

General:

The system shall prevent the distribution of duplicate or invalid information. That means the ACAS server shall send only once RA event data or alteration of existing RA event data.

In case the ACAS ground monitoring system is not able to detect the termination of an RA event, it terminates the event automatically.

Requirement Verification:

During the verification of exercise EXE-15.04.03-VP-300, the received ASTERIX CAT 048 (radar) and ACAS ground station sensor data of real traffic were analysed. There were 9 contributing radars providing surveillance data and 8 contributing ACAS ground station sensors providing RA Event data (see also Figure 1: ACAS Ground Monitoring System). The ASTERIX CAT 004 reports, which the ACAS server sent out, contained RA Event data reports only once in spite of several common contributions.

The verification of the automatic RA termination, if no termination received via sensors, was made by the usage of real traffic and the usage of a simulation tool by replaying and assigning artificially RA events to arbitrary aircrafts. The termination indicator was not set in the RA event data, but the RA event was automatically terminated, as expected, by the ACAS server after 16 seconds.

2.3 Operational Data Interfaces

General:

The main external interfaces of the ACAS Ground Monitoring System are the incoming ASTERIX CAT 048, CAT 021 and CAT 062 (surveillance sensor systems) data interfaces and the outgoing ASTERIX CAT 004 data and status interface to the external systems.

The Raw Data interface of RA event data from the ACAS ground station sensors to the ACAS server is the internal interface.

The entire ACAS ground monitoring system is controlled and monitored by the CMS using the standard SNMP communication protocol.

Requirement Verification:

The verification test EXE-15.04.03-VP-220 has shown that the internal and external interfaces, i.e. ASTERIX, Raw and SNMP, use, as required, the network protocol UDP/IP.
The Raw Data interface and the Surveillance Data interface, i.e. ASTERIX CAT 048, CAT 021 and CAT 062, support the configuration and usage of unicast, multicast and broadcast addresses.

ASTERIX data recording is a basic system function. For that reason the project pays special attention to verify the correct processing and behaviour of the corresponding ASTERIX recording tools for the categories: 004, 021, 048 and 062.

Remark: The surveillance data comprise several potential sources for the target identification information. The project team decided to prefer the target identification coming from ASX CAT 048, if available, because radars have a connection to the flight plan data system.

The Surveillance Data monitoring checks currently only, if the incoming interfaces are busy, that is if the ACAS server can bind to the required channels. It is not monitored, if data are incoming on the activated surveillance data interfaces.

Another observation concerns the structure of the fields “I005/170 Aircraft Identification & Characteristics 1” and “I005/170 Aircraft Identification & Characteristics 2” of ASTERIX CAT 004 Edition 1.52. According to [14] the subfield is defined as shown in Figure 8.

Structure of First Extent:

Octet no. 1

8	7	6	5	4	3	2	1
CDM		PRI	GV	ACV			FX

bit-8/7	(CDM)	Climbing/Descending mode = 00 Maintaining = 01 Climbing = 10 Descending = 11 Invalid
bit 6	(PRI)	= 0 Non primary target = 1 Primary target
bit 5	(GV)	= 0 Default = 1 Ground Vehicle
bits-4/3	(ACV)	ACAS version = 00 RTCA/DO-185 (pre-ACAS) = 01 RTCA/DO-185A = 10 RTCA/DO-185B & EUROCAE ED 143 = 11 Future version
bit-2	spare bit set to zero	
bit-1	(FX)	= 0 End of Data Item = 1 Extension into second extent

Figure 8: ASX CAT 004 ACAS Version

Currently no following octet is defined, which means that the FX bit is always set to '0'. The ASTERIX standard specifies that this octet containing the ACAS version ACV must not be transmitted, if all subfields of the extent contain zeros. Thus this octet is dropped, if CDM, PRI, GV and ACV show the value '0'. Consequently also unknown ACAS version is interpreted as ACAS version "RTCA/DO-185". It is proposed to change this octet as described in the following section Recommendation.

Recommendation:

During verification the project team identified the possibility to improve the operational data output interface. At the moment, the ACAS ground monitoring system uses the involved aircrafts' call-signs, which are not the unique key to combine the RA data to other sources.
Here the project team recommends updating the current ASTERIX CAT 004 edition 1.52 proposals. The project team proposes the usage of the 24-bit ICAO Mode S address, and the addition of the 24-bit ICAO Mode S address to the fields I004/170 and I004/171.

The project team recommends monitoring the incoming data streams of surveillance data. The ACAS server shall output a warning, if an active surveillance data channel does not get any data.

The project team recommends changing the structure and the values of the subfield "ACV" in the fields "I005/170 Aircraft Identification & Characteristics 1" and "I005/170 Aircraft Identification & Characteristics 2" of ASTERIX CAT 004 Edition 1.52 as follows:

Octet No. 1

8	7	6	5	4	3	2	1
CDM		PRI	GV	ACV			FX

bit-8/7	(CDM)	Climbing/Descending mode = 01 Climbing = 10 Descending = 11 Invalid
bit 6	(PRI)	= 0 Non primary target = 1 Primary target

bit 5	(GV)	= 0	Default
		= 1	Ground Vehicle
bits-4/2	(ACV)	ACAS version	
		= 000	Unknown
		= 001	RTCA/DO-185 (pre-ACAS)
		= 010	RTCA/DO-185A
		= 011	RTCA/DO-185B & EUROCAE ED 143
		= 100 - 111	Future versions
bit-1	(FX)	= 0	End of Data Item
		= 1	Extension into second extent

It is recommended that the spare bit 2 is joined with bits 3 and 4 to have a 3-bit representation of the ACAS version subfield. The default value of the ACV subfield shall be ‘0’ meaning ‘Unknown’. The value of all the other ACAS versions shall be incremented by one.

2.4 Management Status and Time Synchronisation

2.4.1 Control and Monitoring System

General:

The system could be controlled by the user from remote and locally. Here the system includes two components to fulfil the task.

During the verification the project team evaluates from remote and locally the

- correct indication of system status (status of ACAS ground station sensors and ACAS server) and
- correct functioning of system configuration (parameter change)

Requirement Verification:

Changes of ACAS ground monitoring system parameters show the expected reaction. In addition, the system supports two kinds of system users: “monitor” and “supervisor”.

Changes of the system parameters are only possible as user “supervisor”.

During the testing the project team triggered several system malfunctions; these disturbances were recognised and indicated correctly by the system.

The following tests were performed with ACAS server and ACAS ground station sensors:

- Start, stop and restart of ACAS ground station sensor
- Start, stop and restart of ACAS Server
- Unplug of network cable (ACAS ground station sensor)
- Unplug of the GPS antenna cable (ACAS ground station sensor)
- Decrement of temperature threshold from 60°C to 30°C (ACAS ground station sensor)
- Change of execution mode from “Operational” to “Maintenance” (ACAS ground station sensor)

While doing so the ACAS server sent the expected ASTERIX CAT 004 status reports with the configured rate.

The reactions of the CMS were as expected. Control and monitoring of the system was possible with the RCMS (remote) as well as with the LCMS (locally connected laptop).

Remark: The network communication between the CMS and the system components is done via SNMP version 3.

Observation:

There is not defined any condition, which let the ACAS server send the status “degraded”. For that reason the ASTERIX CAT 004 status reports showed always the status “operational” and it was not possible to test the event driven transmission of status reports.

The ground station sites on the CMS’ map are displayed in yellow colour (warning). The reason is that the ground station sensors include no UPS for this project. The CMS however expected one UPS per ground station sensor. The problem was solved with the latest SW update: It is not necessary to provide a UPS for every ground station sensor.

Recommendation:

The indication of the current role, i.e. “monitor” or “supervisor”, could be clearer on the CMS.

2.4.2 Time

General:

For correct mode of operation the ACAS Monitoring System components synchronised via a common time source.

Requirement Verification:

The RCMS and the ACAS server were synchronised to a common NTP server. The ACAS ground station sensors are directly synchronised to GPS source. All system components are set to UTC time with a precision of at least 1 millisecond and accuracy of less than 1.2 milliseconds. The jitter and offset of the ground station sensors' clocks is 0, because directly synchronised to GPS.

2.5 Storage, Replay and Record

General:

The ACAS Monitoring system supports two functions:

- Record and storage of received RA event data
- Replay and analyse RA event data

These functions are implemented and verified in the ACAS server and dedicated recording and replay tools. The tools are used to capture all related RA event data on main internal and external interfaces.

The system prototype implies tools for recording and replay of the following data types:

- ACAS RA messages (GS sensor raw data)
- ASTERIX CAT 021 data (GS ADS-B data)
- ASTERIX CAT 048 data (Radar SSR/Mode S data)
- ASTERIX CAT 062 data (Sensor data fusion data)
- ASTERIX CAT 004 data (ACAS Ground Monitoring System operational output data)

The system prototype encompassed the function to store the data into files and to distribute valid RA events to external systems.

These functions/tools/interfaces are tested and evaluated during the system's verification. Deviations from the related requirements specification noted down in this report.

Requirement Verification:

The ACAS server logs every received Raw Data telegram (GS sensor) and Surveillance data (ASTERIX), as required, into dedicated log files. These log files can be used for further offline analysis. Server log files are:

- Data.rec: Recording of all received raw data and surveillance data, e.g.

```
[date    and    time]@asx021;023@    98|186@00000000|11000@    35852.211@    51.52249|
10.75317@06A018@              39625.00@0|0|0|7@00001000@_@              390.00@_@_@_@_@
0.00@0.143738|107.314@_@QTR042  @0@_@0@_@_@_@_@_@_@_@_@_@

[date    and    time]@asx021;023@    98|186@00000000|11000@    35852.227@    53.34452|
9.68790@47844A@_@0|0|0|0@00001000@_@                                    340.00@_@_@_@_@
0.00@0.110840|180.577@_@NAX76Z  @0@_@0@_@_@_@_@_@_@_@_@_@

[date    and    time]@asx021;023@    98|186@00000000|11000@    35852.227@    55.00382|
9.89342@4CA64C@  35925.00@0|0|0|6@00001000@_@  360.00@_@_@_@_@           0.00@0.122253|
0.390@_@RYR8126 @0@_@0@_@_@_@_@_@_@_@_@_@

[date    and    time]@asx021;023@    98|186@00000000|11000@    35852.250@    53.55249|
9.65361@3C4979@              11025.00@0|0|0|7@00001000@_@              109.75@_@_@_@_@
1025.00@0.087341|211.871@_@BER85C  @0@_@0@_@_@_@_@_@_@_@_@_@

[date    and    time]@raw;002@    98|179@0|0|06@1|    35852.364694888@1|0|0|0|2@    -
81.5@2|0@A0001718FFFB8F2CBFFCE1|4CA2C3@
```

- Daily.log: Summary of the RA event telegrams of the day reported by the ASTERIX CAT 048 surveillance data and by the ACAS ground station sensors, e.g.

```
000 098 180 [date and time] 866EBF813A803C07FEFA42BB48EC 0
000 098 180 [date and time] 8646F9623F9A727A0A1AC227AA81 0
000 098 179 [date and time] 817C850D3C4B1899455E8930DB03 0
000 098 177 [date and time] 838F1A9F331200401A43829590FE 0
000 098 179 [date and time] 822914023114000C1E08006E4573 0
002 098 098 [date and time] 30C00008002041 3c5464 1
002 098 098 [date and time] 30C00008002041 406532 1
000 098 188 [date and time] 842AAEFD3D3F65BFFB8013036BCA 0
```

- <data-time-ModeSId>.raw: RA event data of the target ModeSId at the corresponding date and time, e.g.

```
002 098 098 [date and time]30C00008002041 3944eb
002 098 098 [date and time] 30C00008002041 3944eb
002 098 098 [date and time] 30C00008002041 3944eb
002 098 098 [date and time] 30C00008002041 3944eb
002 098 098 [date and time] 30F80008002041 3944eb
002 098 098 [date and time] 30F80008002041 3944eb
002 098 098 [date and time] 30F80028002041 3944eb
002 098 098 [date and time] 30F80028002041 3944eb
```

- <data-time-ModeSId>.vlf: Resolution advisories of the target ModeSId at the corresponding date and time, e.g.

```
08:32:36.695;44ce61;AVSdown;
08:32:43.101;44ce61;AVSup;
```

- <data-time-ModeSId>.trk: RA event data of the target ModeSId merged with surveillance data at the corresponding date and time, e.g.

```
08:53:01.527;7566;3944eb;;370;1894247.0;1807091.0;50.1967;9.9692;
08:53:06.533;7566;3944eb;;370.25;1895611.0;1806997.0;50.1959;9.9883;
08:53:11.534;7566;3944eb;;370.25;1896985.0;1806903.5;50.1950;10.0075;
08:53:16.592;7566;3944eb;;370.25;1898334.5;1806799.5;50.1941;10.0264;
08:53:21.591;7566;3944eb;;370;1899710.5;1806702.5;50.1932;10.0457;
08:53:26.612;7566;3944eb;;370;1901081.0;1806603.5;50.1923;10.0649;
```

All files are ASCII text files and can be read and edited with arbitrary editors. The logging of merged RA events is found in the <data-time-ModeSId>.trk. It was possible to configure the logging time before and after the occurrence of RA events. The logging time is only limited by the integer size 65535 and is to be entered in seconds.

The recorded data in the file data.rec containing ground station sensor data and surveillance data are uniquely identified by their data source and the time stamp.

Available RA Event attributes in the log files are

- Aircraft identification of the reporting aircraft
- Aircraft address of the reporting aircraft
- Type of the resolution advisory, i.e. the ARA field, if available
- Source of the resolution advisory event data (RA Broadcast UF16, UDS3,1 or Resolution Advisory Message UF16, UDS3,0 or Coordination message DF16, VDS3,0)
- Time stamp of the RA event
- Termination indicator
- Call sign in the corresponding <data-time-ModeSId>.trk file.

3 Conclusions and Recommendations

3.1 Synopsis of System Verification Task

The system verification has been realized by the project team in parallel to the final data collection and evaluation task (T10) and the execution of the system evaluation task (T05). Baseline for the verification was the high-level systems specifications whereby the verification results were noted down in the verification template document.

Requirement Identifier	Requirement description	Synopsis
REQ-15.04.03-TS-GE10.0010	The ACAS Ground Monitoring System **shall** be able to detect messages from aircraft equipped with TCAS II versions 6.04a, 7.0 and 7.1.	The ACAS versions RTCA/DO-185A and RTCA/DO-185B were interpreted and sent in the ASTERIX CAT 004 data as expected. The interpretation of a missing ACV subfield in ASTERIX reports as RTCA/DO-185 has been seen unreliable.
REQ-15.04.03-TS-GE10.0030	The ACAS ground station sensor **shall** detect ACAS RA messages with a minimum probability (PD) of 95% at MTL +3dB.	The 1090 MHz ground station sensors fulfilled the requirement with an MTL equal to the sensitivity described in the ground station sensor's manual: PD of 99.8% This was not the case with 1030 MHz ground station sensors: PD of 76% The actual MTL of the 1030 MHz and 1090 MHz ground station sensor should be added to the user manual of the ground station sensors.
REQ-15.04.03-TS-GE10.0040	An ACAS Ground Monitoring System **shall** enfold at minimum the following base functions: • Function for RA reception and decoding • Function for RA information acquisition, correlation and filter • Function for RA information storage • Function for RA information distribution • Function for RA information replay • Function for system monitoring and control Function for system time synchronisation	The ACAS Ground Monitoring System under test fulfilled the base functions of an ACAS Ground Monitoring System.
REQ-15.04.03-TS-	The ACAS Ground Monitoring System **shall** consist of a set of one or more	The signal generator injected arbitrary defined uplink and downlink telegrams

Requirement Identifier	Requirement description	Synopsis
GE10.0050	receive-only ACAS ground station sensor(s) being able to detect, to decode and to process Mode-S signals received on the 1090 MHz channel.	into the ground stations. UF 16 and DF 16 were among the injected data. The injected telegrams were displayed on the Raw Recording tool and found in the raw data log file.
REQ-15.04.03-TS-GE10.0060	The ACAS Ground Monitoring System **shall** consist of a set of one or more receive-only ACAS ground station sensor(s) being able to detect, to decode and to process Mode-S signals received on the 1030 MHz channel.	
REQ-15.04.03-TS-GE10.0070	The ACAS Ground Monitoring System **shall** be able to decode and process aircraft transponder messages complying as specified in EUROCAE/RTCA MOPS ED102A/DO-260B §2.2.3.2.7.8.2 (FTC=28 – Subtype=2).	The test of this requirement was verified with exercise "EXE-15.04.05.a-TS.0060.0265 GS: ACAS Resolution Advisory Report" of the paper 15.04.05.b-D07-First Iteration-Verification-Acceptance-Report.
REQ-15.04.03-TS-GE10.0080	The ACAS Ground Monitoring System **shall** be able to process simultaneously at minimum 10 RA events. Note: The ACAS Ground Monitoring System will be suitable for use for the anticipated traffic numbers in core Europe until at least 2030.	The tests passed successfully, but note that RA events from targets with non-unique Mode 3/A Codes are to be ignored and generate no alarm. This behaviour is as expected. The ACAS Ground Monitoring System is currently not obliged to make tracking to find the reporting target.
REQ-15.04.03-TS-GE10.0090	The ACAS Ground Monitoring System time **shall** be synchronized by an internal or external time source.	RCMS and ACAS Server were synchronised to several ACAS ground station sensor. The ACAS Ground Station sensors were directly synchronised to GPS.
REQ-15.04.03-TS-GE10.0100	The ACAS Ground Monitoring System **shall** use Coordinated Universal Time (UTC) time as time base.	The test passed with success, because all logs, clocks, applications and operating systems based on UTC; as required.
REQ-15.04.03-TS-GE10.0110	The ACAS Ground Monitoring System **shall** use a system time with a maximum resolution of 1/128 second.	The test passed without observation, because the time stamps in the log files and the time stamps of the recorded data on the RCMS show a resolution of 0.0078125 s or better.
REQ-15.04.03-TS-PR10.0160	The resolution of the time stamps in the ACAS ground station sensors **shall** be at maximum 1/128 seconds.	
REQ-15.04.03-TS-PR10.0320	The resolution of the time stamp in the ACAS server **shall** be at maximum 1/128 seconds.	
REQ-15.04.03-TS-GE10.0120	The ACAS Ground Monitoring System **shall** use a system time with	The time accuracies of the respective ACAS Ground Monitoring Systems:

Requirement Identifier	Requirement description	Synopsis
	accuracy better than ± 2ms.	ACAS Server: Sum of offset and squitter was less than 0.2 ms RCMS: Sum of offset and squitter was less than 1.2 ms GS: 0 ms as expected, because directly synchronised to GPS.
REQ-15.04.03-TS-PR10.0020	The ACAS Ground Monitoring System **shall** provide ACAS RA messages on the external ACAS Ground Monitoring System output interface.	ASTERIX CAT 004 output of the ACAS server is a basic feature being tested with every exercise concerning the processing of RA events.
REQ-15.04.03-TS-PR10.0360	The ACAS Ground Monitoring System **shall** provide information to external systems by using ASTERIX Category 004 edition 1.5 (SESAR WP15.4.3 proposal).	
REQ-15.04.03-TS-GE10.0130	The ACAS Ground Monitoring System **shall** provide RA event data to external systems via Standard ASTERIX CAT 004 protocol for Online Processing.	
REQ-15.04.03-TS-RR10.0030	The ACAS Ground Monitoring System **shall** provide a function to record data sent out by the system.	
REQ-15.04.03-TS-GE10.0140	The ACAS Ground Monitoring System **shall** provide RA event and related Surveillance Sensor data for Offline Processing and Analysis.	The possibility to make offline processing and analysis was possible with the help of the log files data.rec, daily.log and the files *.vlf, *.raw and *.trk, which were found on the ACAS server.
REQ-15.04.03-TS-GE10.0150	The ACAS Ground Monitoring System **shall** provide information on the external ACAS Ground Monitoring System output interface within 2 seconds from the time the RA is generated in 95% or more of the cases.	The latency of the considered ACAS Ground Monitoring System was far below the maximum required limit of two seconds, it was maximal 600 milliseconds.
REQ-15.04.03-TS-GE10.0160	The ACAS monitoring ground station sensor(s) and the ACAS server **shall** store system configuration parameters persistent in a non-volatile memory.	Changes of the configurations were only possible, if the user had the role supervisor. Configuration changes of the ACAS server and ACAS ground station sensors were possible. The changes became active, if the load-button was hit, and became persistent, if the save-button was pushed.
REQ-15.04.03-TS-GE10.0220	During start-up, the system (Ground station sensor(s) and the ACAS server) **shall** read-out and use system configuration parameters from the non-volatile memory.	
REQ-15.04.03-TS-PR10.0030	The ACAS Ground Monitoring System **should** be able to receive, decode and process Surveillance information	The following access required user name and password: • LCMS

Requirement Identifier	Requirement description	Synopsis
	provided by the Surveillance Sensor Systems: SSR-Mode-S, ADS-B and Sensor Data Fusion system (SDF).	• RCMS • Remote login to ACAS ground station sensors • Remote login to ACAS server • Login to LDAP data base of the Control and Monitoring agent Files and directories were equipped with access rights being usual for UNIX/LINUX systems The user had to be supervisor or root to be able to change the configuration parameters.
REQ-15.04.03-TS-GE10.0170	The ACAS Ground Monitoring System **shall** prevent unauthorized user access to system components and system data.	
REQ-15.04.03-TS-GE10.0180	The ACAS Ground Monitoring System **shall** be controlled and monitored by an autonomous Control and Monitoring System (CMS).	The problem with wrong rendering of ground station sensor states were solved with changes of the following parts of the MTSC concept: - UPS is not mandatory for every ground station sensor anymore. - Single-single role combination of 1030 MHz/1090 MHz ground station pairs is allowed.
REQ-15.04.03-TS-GE10.0190	The ACAS Ground Monitoring System **shall** be controllable by a system user from remote.	The RCMS allowed to configure and to control the ACAS ground station sensors and the ACAS server from remote.
REQ-15.04.03-TS-GE10.0200	The ACAS Ground Monitoring System **shall** be local controllable by a system user.	The LCMS could be connected via network like the RCMS or directly to the ACAS ground station sensors. On the LCMS the same applications for configuration of the ACAS server and sensors were found as on the RCMS.
REQ-15.04.03-TS-GE10.0210	The ACAS ground monitoring ground station sensor(s) and the ACAS server **shall** start automatically after system blackout.	The power cable of the ACAS server was plugged off. After reconnection of the power cable the ACAS Server started automatically and switched to operational as expected.
REQ-15.04.03-TS-PR10.0010	The ACAS Ground Monitoring System **shall** be able to receive, decode and process ACAS RA messages.	The successful reception of Aircraft Status squitters conveying Resolution Advisory Reports was verified with exercise EXE-15.04.03-VP-010. With the help of a message generator DF16 and UF16 telegrams were injected to the 1090 MHz and 1030 MHz ACAS ground station sensors. The raw recording on the RCMS confirmed the successful reception of the injected signals. The data.rec file contained the injected signals as well.
REQ-15.04.03-TS-	The ACAS Ground Monitoring System	Checking the file data.rec on the ACAS

Requirement Identifier	Requirement description	Synopsis
PR10.0170	**should** be able to receive and process Surveillance data provided by a Sensor Data Fusion (SDF) system in ASTERIX Category 62 edition 0.27.	server showed that the ACAS server was able receiving ASTERIX CAT 048, ASTERIX CAT 021 and ASTERIX CAT 062 reports.
REQ-15.04.03-TS-PR10.0180	The ACAS Ground Monitoring System **should** be able to receive and process Surveillance data in ASTERIX Category 48 edition 1.15.	
REQ-15.04.03-TS-PR10.0190	The ACAS Ground Monitoring System **should** be able to receive and process Surveillance data in ASTERIX Category 21 edition 0.23.	
REQ-15.04.03-TS-PR10.0040	The ACAS Ground Monitoring System **shall** provide connection to external systems via UDP/IP.	UDP data were found on the Raw Data, ASTERIX CAT 021 and ASTERIX CAT 004 data interfaces.
REQ-15.04.03-TS-PR10.0050	ACAS Ground Monitoring System network addresses **shall** be configurable by the system user.	The network interfaces were configurable by the system user 'supervisor'.
REQ-15.04.03-TS-PR10.0070	ACAS Ground Monitoring System network ports **shall** be configurable by the system user.	
REQ-15.04.03-TS-PR10.0060	The ACAS Ground Monitoring System **shall** support unicast, multicast and broadcast network addresses.	The ACAS Ground Monitoring System is able providing unicast, multicast and broadcast network addresses on its internal and external network interfaces.
REQ-15.04.03-TS-PR10.0080	The ACAS Ground Monitoring System **shall** be able to receive, decode and process the Mode-S uplink (UF-0 to UF-24) telegram formats as defined in ICAO Annex 10 Volume 4.	The following downlink and uplink formats were injected to the ACAS ground station sensor with the help of a signal generator: Downlink Formats: DF0, DF04, DF11, DF16, DF17, DF21 Uplink Formats: UF04, UF11, UF16 All the injected telegrams could be found on the display of the Raw Recording tool running on the RCMS with the time stamp of arrival.
REQ-15.04.03-TS-PR10.0090	The ACAS Ground Monitoring System **shall** be able to receive, decode and process the Mode-S downlink (DF-0 to DF-24) telegram formats as defined in ICAO Annex 10 Volume 4.	
REQ-15.04.03-TS-PR10.0150	The ACAS monitoring ground station sensor **shall** mark each incoming received Mode-S telegram by a unique system time stamp.	
REQ-15.04.03-TS-PR10.0100	The ACAS Ground Monitoring System **shall** be able to filter Mode-S uplink (UF-0 to UF-24) telegram formats as defined in ICAO Annex 10 Volume 4.	The filtering of Mode S telegram formats was possible.
REQ-15.04.03-TS-PR10.0110	The Mode-S Uplink telegram format filter **shall** be configurable by the system user.	

Requirement Identifier	Requirement description	Synopsis
REQ-15.04.03-TS-PR10.0120	The ACAS Ground Monitoring System **shall** be able to filter Mode-S downlink (DF-0 to DF-24) telegram formats as defined in ICAO Annex 10 Volume 4.	
REQ-15.04.03-TS-PR10.0130	The Mode-S Downlink telegram format filter **shall** be configurable by the system user.	
REQ-15.04.03-TS-PR10.0140	The ACAS ground monitoring ground station sensors **shall** be able to send decoded Mode-S telegrams over a network to local and remote installed processing units.	It was possible to configure the ACAS ground station sensors in that way that they have sent the raw data via network to a configurable network address.
REQ-15.04.03-TS-RR10.0010	Recording functions shall be able to receive decoded Mode-S telegrams from ACAS monitoring ground station sensors over network	
REQ-15.04.03-TS-PR10.0200	The ACAS Ground Monitoring System **shall** be able to filter incoming ACAS ground station sensor data based on the ACAS ground station sensor.	The filter must be set in the configuration by hand with an arbitrary editor. If there are no filter entries in the configuration file, then all telegrams pass. Once there is an entry in the filter configuration, then only those telegrams pass, which are listed in the configuration file. The data source filter applied to Surveillance and to RA Event data.
REQ-15.04.03-TS-PR10.0210	The ACAS ground station sensor filter **shall** be configurable by the system user.	
REQ-15.04.03-TS-PR10.0220	The ACAS Ground Monitoring System **shall** be able to filter incoming Surveillance Sensor data based on the surveillance data source.	
REQ-15.04.03-TS-PR10.0230	The Surveillance data source filter **shall** be configurable by the system user.	
REQ-15.04.03-TS-PR10.0240	The ACAS Ground Monitoring System **shall** provide functions to read, process and merge received incoming ACAS ground station sensor data messages and Surveillance data messages.	The RA event and surveillance data were merged and corresponding ASTERIX CAT 004 reports were received at the recorder on the RCMS.
REQ-15.04.03-TS-PR10.0250	The ACAS Ground Monitoring System **shall** provide functions to store received incoming ACAS ground station sensor data messages and Surveillance data messages.	The ACAS server provided the following log files logging continuously data in ASCII format: • Data.rec: Recording of all received raw data and surveillance data • Daily.log: Summary of the RA event telegrams of the day reported by the ASTERIX CAT 048 surveillance data and by the
REQ-15.04.03-TS-PR10.0260	Incoming ACAS ground station sensor data messages **shall** continuously be stored into a user readable file. (ASCII format).	

Requirement Identifier	Requirement description	Synopsis
	Note: The storage could also be a database.	ACAS ground station sensors. • <data-time-ModeSId>.raw: RA event data of the target ModeSId at the corresponding date and time • <data-time-ModeSId>.vlf: Resolution advisories of the target ModeSId at the corresponding date and time • <data-time-ModeSId>.trk: RA event data of the target ModeSId merged with surveillance data at the corresponding date and time
REQ-15.04.03-TS-PR10.0270	Surveillance data **shall** be stored within a user defined period, i.e. a number of minutes before an aircraft RA acquisition by the system and number of minutes after an aircraft RA termination.	It was possible to configure recording time spans even up to 65535 seconds before and after the RA event.
REQ-15.04.03-TS-PR10.0280	The system user **shall** be able to configure the Surveillance data storage time span.	
REQ-15.04.03-TS-PR10.0290	This time span **shall** be between 1 and 15 minutes before and after an RA event.	
REQ-15.04.03-TS-PR10.0300	The system **shall** mark each recorded ACAS ground station sensor data message and Surveillance data message in the file by a unique identifier (source) and its reception time.	The data source SIC/SAC coupled with the date and time in milliseconds were the primary key of the raw data file data.rec containing raw data from ACAS ground station sensors and ASTERIX Surveillance data.
REQ-15.04.03-TS-PR10.0310	The ACAS server **shall** mark incoming received ACAS RA messages and Surveillance data messages by a unique system time stamp.	
REQ-15.04.03-TS-PR10.0330	The ACAS server **should** mark incoming received ACAS RA messages, ACAS broadcast messages and Surveillance data messages by a unique system origin identifier.	
REQ-15.04.03-TS-PR10.0340	The ACAS Ground Monitoring System **shall** provide the following information when an RA event occurs and when there is a change. • Aircraft identification (call sign or registration)	For every concerned aircraft, the: • *.vlf log file contains the Mode S address, the type of resolution advisory and the time stamp • *.trk log file contains the Mode S address, the Mode 3/A code, the

Requirement Identifier	Requirement description	Synopsis
	• Aircraft address (24 bit Mode S address) • Type of the RA, if available (ARA field as specified in [8]) • Source of information (RA DL, Broadcast or Coordination message • Time stamp (resolution 1/128 s)	altitude, the position • *.raw log file contains the sources of the resolution advisory event, the time stamp and the Mode S address
REQ-15.04.03-TS-PR10.0350	The ACAS Ground Monitoring System (ACAS server) **should** additionally provide the following information when an RA event occurs. In case of a threat indicated as Mode S equipped (TTI=1) in received messages. • Threat aircraft address (24 bit Mode S address) In case of a threat indicated as not Mode S equipped (TTI=2) in received messages. • Threat aircraft altitude, range and bearing • Threat aircraft Mode A code (when possible)	The test passed, because it covered only an optional requirement. Information about the threat are present in the ACAS Server, but were not logged to any file.
REQ-15.04.03-TS-PR10.0370	The ACAS Ground Monitoring System **shall** provide a data fusion function to suppress duplicated ACAS RA messages and duplicated Surveillance data messages.	The ASTERIX CAT 048 data of real traffic was observed. There were 9 contributing radars providing surveillance data and 7 contributing ACAS ground station sensors providing RA Event data. ASTERIX CAT 004 reports contained RA Event data only once in spite of several radars contributing surveillance data and several ACAS ground station sensors providing RA events.
REQ-15.04.03-TS-PR10.0390	The ACAS Ground Monitoring System **shall** validate all incoming ACAS RA messages to filter out technical error cases (e.g. empty data fields, missing threat data and undefined data in data fields received).	RA Event messages in the log file daily.log were marked as not used, if no correlation was possible or if the messages were invalid.
REQ-15.04.03-TS-PR10.0410	The ACAS Ground Monitoring System **shall** mark each invalid ACAS RA messages.	
REQ-15.04.03-TS-	In case the ACAS Ground Monitoring	The ACAS server terminated a resolution

Requirement Identifier	Requirement description	Synopsis
PR10.0420	System is not receiving RA termination, the RA termination **shall** be declared 16 seconds after reception of the last ACAS RA message.	advisory event automatically after 16 seconds.
REQ-15.04.03-TS-PR10.0430	The ACAS Ground Monitoring System **shall** provide the following summary RA information per RA event. • Date • Time (UTC) with a resolution of at maximum 1/128 seconds • Aircraft 1 identification (call sign or registration) • Aircraft 1 address (24 bit Mode S address) • Type of the RA (ARA field as specified in [8]) • Geographical location of event (LAT/LON in WGS84) In case of a threat indicated as Mode S equipped (TTI=1) in received messages. • Aircraft 2 address (24 bit Mode S address) In case of a threat indicated as not Mode S equipped (TTI=2) in received messages. • Aircraft 2 altitude, range and bearing • Aircraft 2 Mode A code, when possible	The test passed successfully, because all mandatory data could be found in the log files provided by the ACAS Server. The data of the threat were not mandatory according to requirement REQ-15.04.03-TS-PR10.0350. It was recommended to provide them.
REQ-15.04.03-TS-RR10.0040	The ACAS Ground Monitoring System **shall** provide a function to replay recorded data.	Thus the recording and replay tools worked correctly and were even able correcting some false ASTERIX CAT 004 data.
REQ-15.04.03-TS-SU10.0010	The ACAS monitoring ground station sensor **shall** automatically and periodically perform a self-testing function (BITE) in parallel to the normal operation.	The following error conditions were generated in the ACAS ground station sensor: • The CMS indicated a warning, if the configuration changes were done, but not saved to disk • Switched to colour red, when pulling the network cable at the ACAS ground station sensor • Changed execution mode to "Maintenance" for the 1090 MHz
REQ-15.04.03-TS-SU10.0080	The Control and Monitoring system **shall** control and monitor the following ACAS system components: • N x ACAS ground station sensor(s)	

Requirement Identifier	Requirement description	Synopsis
	• N x ACAS server(s)	receiver of the ground station sensor LANGEN: No ASTERIX and no Raw Data were received as expected. • Disabling of the Raw Data stream in ACAS ground station sensor LANGEN: GS changed to 'yellow' (warning), because parameter has been changed, but not saved. Raw data were not received as expected. • Decrement of temperature limit from 60°C to 30°C in 1090 MHz sensor of LANGEN: Change to warning state 'yellow' • Pulling GPS antenna to get a time synchronisation error: the 1030 MHz and 1090 MHz of the ground station sensor LANGEN turned to warning state 'yellow' and after a while to error state 'red'. • 1090 MHz sensor of LANGEN switched to colour green after recover of the provoked problems, respectively. The following error conditions were generated in the ACAS server: • The CMS indicates a warning, if the configuration changes were done, but not saved to disk • Switch to error state 'red' after stop of ACAS server • Switch to state 'green' after restart of ACAS server
REQ-15.04.03-TS-SU10.0020	The ACAS server **shall** automatically and periodically perform a self-testing function (BITE) in parallel to the normal operation.	
REQ-15.04.03-TS-SU10.0030	The ACAS server **shall** be able to send out its current system status in ASTERIX Category 004 edition 1.5 (SESAR WP15.4.3 proposal).	This test passed, although a part of it could not be tested, because no error conditions of the ACAS server are defined.
REQ-15.04.03-TS-SU10.0040	ACAS server **shall** be able to send out system status reports event-driven and periodically.	
REQ-15.04.03-TS-SU10.0050	In case of a periodically system status reporting mode, the ACAS server status update rate **shall** be adjustable between 1 and 60 seconds.	
REQ-15.04.03-TS-SU10.0060	The ACAS Ground Monitoring System **shall** be able to monitor the status of the Surveillance Data interface.	The monitoring of surveillance data was implemented and correctly tested with ACAS-0.90. However, it was proposed to

Requirement Identifier	Requirement description	Synopsis
REQ-15.04.03-TS-SU10.0070	The activation or de-activation of the Surveillance Data Interface Monitoring **shall** be configurable by the system user.	expand the monitoring in the way, that enabled incoming surveillance data interface must permanently receive data.
REQ-15.04.03-TS-SU10.0090	The ACAS Ground Monitoring System and the associated Control and Monitoring System (CMS) **shall** use the standard management network protocol SNMP V2 or higher for communication.	The ACAS Ground Monitoring System used SNMP version 3 commands to monitor the ACAS monitoring system components GS sensors and ACAS server.

3.2 Final Conclusion

The verification tests have shown that the ACAS Ground Monitoring system prototype is capable to receive, decode and correlate RA Event and Surveillance data correctly. It supports all main functions of an ACAS ground monitoring system and is useable to record and analyse RA Events.

It is recommended that every point of the coverage area is within the range of at least two ACAS ground station sensors to guarantee a steady monitoring of RA events, even if there is a failure of sensor.

Some recommendations concern the graphical user interface of the Control and Management System. Operational use will require some changes to satisfy the needs of maintenance staff.

The Surveillance Data Monitoring function of the ACAS server shall additionally check on continuous incoming data streams of activated surveillance data channels.

The ACAS server shall be enabled to process consecutive RA events of one target within configurable time intervals after a termination of an event.

A necessary change of the ASTERIX CAT 004 protocol is the addition of the ICAO 24 Bit address of the concerned aircrafts involved in an RA event to ease error and offline analysis of RA events. Another change of the ASTERIX CAT 004 concerns the subfield ACV, in the fields I004/170 and I004/171, which shall provide the additional value “Unknown”.

An additional tracking function in the ACAS Ground Monitoring would be needed, if

- Track data of Mode A/C threats will be required.
- RA events from an aircraft being only identified by a non-unique Mode 3/A code shall be processed

The tests have shown that the considered ACAS ground monitoring system is capable to support the requirements of a fully operational system.

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